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**TECHNICAL REPORT  
NATICK/TR-77/009**

# **RADAPPERTIZATION (RADIATION STERILIZATION) OF FOODS**

**Irradiated Food Products Group  
Radiation Preservation of Food Division**

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**December 1976**

**UNITED STATES ARMY  
NATICK RESEARCH and DEVELOPMENT COMMAND  
NATICK, MASSACHUSETTS 01760**



**FOOD ENGINEERING LABORATORY  
FEL-62**

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report is a bibliography of technical publications and papers on radappertized (radiation sterilized) foods written by scientific personnel of the U.S. Army Natick Research and Development Command and other scientists working in or responsible for the part of the National Radiation Preservation of Food Program dealing with radiation-sterilization processing of prepackaged, shelf-stable foods, mainly red meats, poultry, and selected seafoods. The report includes 230 documents published within the		

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20. period March 1962 through December 1976, subdivided into books, technical reports, patents, technical papers (NARADCOM) and articles in scientific and technical journals.

Index of authors with their corresponding entry numbers are included for easy search of the publications by the names of the authors.

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## PREFACE

Numerous requests from the food industry and academic and research institutions in the United States and abroad about the status and progress made in the field of radappertized (radiation sterilized) shelf-stable foods prompted updating of the bibliography report first published in June 1973 as Technical Report 74-3-FL. This bibliography is a list of technical publications and papers by scientific personnel of the US Army Natick Research and Development Command (NARADCOM) working in or responsible for the part of the National Radiation Preservation of Food Program dealing with high-dose radiation processing of prepackaged, shelf-stable foods.

In addition, the compilation contains contractors' reports and a few selected books which have been either edited by or contain papers contributed by NARADCOM personnel. In the book section are listed five periodic reviews of the food radiation program by the Joint Committee on Atomic Energy, Congress of the United States, which continuously encourages and supports the food irradiation program under the "Atoms for Peace" program.

We have also included a listing of selected papers pertaining to food processing by irradiation that have been published in the Journal of Food Science and not listed elsewhere in this bibliography.

The period covered by this bibliography is March 1962 through December 1976. The bibliography, subdivided into six groups, is arranged chronologically by the date of publication. We have also included an indexing system to allow for easier and more frequent updating of the bibliography and to make it easier to use for reference.

During that period this installation was renamed from US Army Natick Laboratories to US Army Natick Development Center, and finally to US Army Natick Research and Development Command (NARADCOM).



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## RADAPPERTIZATION OF FOODS

### I. BOOKS

- B-1-T REVIEW OF AEC AND ARMY FOOD IRRADIATION PROGRAMS.  
Hearings before the Subcommittee on Research, Development and Radiation of the Joint Committee on Atomic Energy, Congress of the United States (JCAE), Eighty-Seventh Congress, Second Sessions, March 6 and 7, 1962. Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402  
Price \$3.00
- B-2-T REVIEW OF THE ARMY FOOD IRRADIATION PROGRAM.  
Hearing, JCAE, Eighty-Eighth Congress, First Session, 13 May 1963. Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402  
Price \$1.50
- B-3-T RADIATION PROCESSING OF FOODS.  
Hearings, JCAE, Eighty-Ninth Congress, First Sessions, 9 and 10 June 1965. Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402  
Price \$2.50
- B-4-T REVIEW OF THE FOOD IRRADIATION PROGRAM.  
Hearing, JCAE, Eighty-Ninth Congress, Second Session, 12 September 1966. Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402  
Price \$1.00
- B-5-T STATUS OF THE FOOD IRRADIATION PROGRAM.  
Hearings, JCAE, Ninetieth Congress, Second Sessions, 18 and 20 July 1968. Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402  
Price \$3.00
- B-6-T THE TECHNICAL BASIS FOR LEGISLATION ON IRRADIATED FOOD.  
Report of a Joint FAO/IAEA/WHO Expert Committee, Rome, 21-28 April 1964. FAO, Atomic Energy Series No. 6, Food and Agriculture Organization of the United Nations, Rome 1965.
- B-7-E CURRENT STATUS AND COMMERCIAL PROSPECTS FOR RADIATION PRESERVATION OF FOOD.  
H. W. Ketchum, J. W. Osburn, Jr., and J. Deitch. TID-21431, BDSA U. S. Department of Commerce, Washington, DC 20230. January 1965. (174 pages, 185 references).

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- B-8-T RADIATION PRESERVATION OF FOODS.  
Proceedings, International Conference, Boston, MA, 27-30 September 1964; Publication 1273, National Academy of Sciences-National Research Council, Washington, DC 20418, 1965. (37 papers, 424 pages).  
Price \$9.00
- B-9-T FOOD IRRADIATION.  
Proceedings, International Symposium on Food Irradiation, The International Atomic Energy Agency and the Food and Agriculture Organization of the United Nations, Karlsruhe, Germany, 6-10 June 1966; STI/PUB/127, International Atomic Energy Agency, P.O. Box 590, (67 papers, 956 pages).  
Price \$20.00
- B-10-T CHEMICAL AND FOOD APPLICATIONS OF RADIATION.  
60th National Meeting of the American Institute of Chemical Engineers. Atlantic City, NJ, 18-21 September 1966. Chemical Engineering Progress Symposium Series, No. 83, Vol. 64, 1968 - American Institute of Chemical Engineers, 345 E. 47th Street, New York, NY 10017. (16 papers, 149 pages).
- B-11-T RADIATION PRESERVATION OF FOODS.  
A symposium co-sponsored by the Division of Agricultural and Food Chemistry and the Division of Nuclear Chemistry and Technology at the 150th Meeting of the American Chemical Society, Atlantic City, NJ, 16-17 September 1965. Advances in Chemistry Series 65, American Chemical Society, Washington, DC, 1967 (15 papers, 184 pages).  
Price \$7.00
- B-13-E THE COMMERCIAL PROSPECTS FOR SELECTED IRRADIATED FOODS.  
TID-24058, BDSA, US Department of Commerce, Washington, DC 20230, March 1968. (90 pages, 154 references).  
Price \$ .50
- B-14-T RADIATION PROCESSING OF FOOD PRODUCTS.  
L. V. Metlitskii, V. N. Rogachev, and V. G. Krushchev, Moscow, USSR, 1967. ORNL-IIC-14, July 1968. Translated from original Russian by Oak Ridge National Laboratory, Oak Ridge, TN, for the US Atomic Energy Commission. Edited by M. Gerrard, F. E. McKinney, P. S. Baker, and E. Wierbicki. US Department of Commerce, National Technical Information Services, Springfield, VA 22161 (115 pages, 32 references).  
Price \$3.00
- B-15-M ELIMINATION OF HARMFUL ORGANISMS FROM FOOD AND FEED BY IRRADIATION.  
Proceedings of a Panel, Zeist, 12-16 June 1967, International Atomic Energy Agency, Vienna, 1968.

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- B-16-T PRESERVATION OF FRUIT AND VEGETABLES BY RADIATION.  
Proceedings of a Panel, Vienna, 1-5 August 1966, International Atomic Energy Agency, Vienna, 1968.
- B-17-O TRAINING MANUAL OF FOOD IRRADIATION TECHNOLOGY AND TECHNIQUES.  
International Atomic Energy Agency, Vienna, 1970.
- B-18-P PRESERVATION OF FISH BY IRRADIATION.  
Proceedings of a Panel, Vienna, 15-19 December 1969.  
International Atomic Energy Agency, 1970.
- B-19-P DISINFESTATION OF FRUIT BY IRRADIATION.  
Proceedings of a Panel, Honolulu, 7-11 December 1970,  
International Atomic Energy Agency, Vienna, 1971.
- B-20-E COST-BENEFITS ANALYSIS.  
Potential Radiation Sterilized Military Subsistence Items.  
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Department of Commerce, Bureau of Domestic Commerce, March  
1972. Superintendent of Documents, US Government Printing  
Office, Washington, DC 20402 (150 pages, 66 references).  
Price 1.25
- B-21-C RADIATION RESEARCH REVIEWS.  
Symposium on the Recent Advances in the Chemistry of Food  
Irradiation, 161st National Meeting, The American Chemical  
Society, Division of Agricultural Chemistry, 1 April 1971,  
Los Angeles, CA. Edited by E. S. Josephson and C. Merritt,  
Jr., Vol 3 (4): 281-460 (completing Vol. 3), July 1972.  
Elsevier Publishing Company, P.O. Box 211, Amsterdam, The  
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- B-22-T RADIATION PRESERVATION OF FOOD.  
Proceedings, IAEA/FAO Symposium, Bombay, India, 13-17  
November 1972, STI/PUB/317. Proceeding Series, Vienna, 1973.  
International Atomic Agency, Vienna, Austria. (51 papers,  
774 pages).  
Price \$30.00
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International Atomic Energy Agency, Kaerntner Ring 11, P.O.  
Box 590, A-1011, Vienna, Austria. STI/PUB/331, February 1973.

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B-24-T ASPECTS OF THE INTRODUCTION OF FOOD IRRADIATION IN DEVELOPING COUNTRIES.

Proceedings of a Panel by the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture, Bombay, India 18-22 November 1972. International Atomic Energy Agency, Kaerntner Ring 11, P.O. Box 590, A-1011, Vienna, Austria. STI/PUB/362, December 1973.

B-25-T IMPROVEMENT OF FOOD QUALITY BY IRRADIATION.

Proceedings of a Panel, Vienna, 18-22 June 1973, International Atomic Energy Agency, Vienna, 1974.

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R-1-P EXTRACTIVES AND FUNCTIONAL PERFORMANCE OF FLEXIBLE PACKAGING MATERIALS FOR USE IN RADIATION STERILIZATION OF PREPACKAGED FOODS.

G. O. Payne, Jr. and C. H. Speigl. (Continental Can Company, Contract No. DA19-129-AMC-162(n); Project Officer, NLABS - J. J. Killoran). FD-3, December 1964 (AD 455 946).

R-2-C INDUCED RADIOACTIVITY IN FOOD AND ELECTRON STERILIZATION.

R. A. Meyer. (US Army Natick Laboratories). FD-6, April 1965 (AD 613 950).

R-3-T INVESTIGATION OF THE USE OF VERY HIGH DOSE RATES FOR THE RADIATION PRESERVATION OF PROTEIN FOOD.

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R-4-S CALCULATED INTERNATIONAL RADIATION DOSE FROM INGESTION OF MEAT STERILIZED BY ELECTRON IRRADIATION.

T. G. Martin, III. (US Army Natick Laboratories). 66-26-FD, April 1966 (AD632 360).

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R-6-T EFFECT OF LOW TEMPERATURE IRRADIATION ON CHEMICAL AND SENSORY CHARACTERISTICS OF BEEF STEAKS.

F. L. Kauffman and J. W. Harlan. (Swift and Company, Contract No. DA19-129-AMC-164(N); Project Officer, NLABS - E. Wierbicki). 69-74-FL, March 1969 (AD 687 340).

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- R-8-M MODE OF RADIATION RESISTANCE OF CLOSTRIDIUM BOTULINUM SPORES.  
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- R-9-N EFFECT OF IRRADIATION DOSE AND TEMPERATURE ON THE THIAMINE CONTENT OF HAM.  
M. H. Thomas and E. Wierbicki. (US Army Natick Laboratories). 71-44-FL, January 1971 (AD 726 380).
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- R-11-T DEVELOPMENT OF COOKING PROCEDURES AND RECIPES FOR USING IRRADIATION STERILIZED MEATS.  
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- R-12-T IRRADIATION STUDIES ON MEAT.  
J. W. Harland and F. L. Kauffman. (Swift and Company, Contract No. 172; NLABS Project Officer - F. Heiligman). 72-32-FL, January 1972 (AD 736 360).
- R-13-P EFFECT OF IONIZING RADIATION ON PHYSICAL AND CHEMICAL PROPERTIES OF FIBERBOARD AND PAPERBOARD.  
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L. J. Ronsivalli. (US Department of Interior, Bureau of Commercial Fisheries, Project Order No. 66-68; Project Officer, NLABS - F. Heiligman). 72-42-FL, February 1972 (AD 739 497).
- R-15-C IRRADIATION INDUCED HEADSPACE GASES IN PACKAGED RADIATION STERILIZED FOOD.  
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J. C. Humphreys, S. E. Chappell, W. L. McLaughlin, and R. D. Jarrett. NBSIR 73-413, November 1973.
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- R-20-T EFFECTS OF CONDENSED PHOSPHATES ON THE pH, WATER-HOLDING CAPACITY AND MEAT SWELLING PROPERTIES OF PORK MUSCLE.  
G. W. Shults and E. Wierbicki (US Army Natick Laboratories). TR-74-22-FL, January 1974 (AD 776 336).
- R-21-T MEASUREMENT OF COHESIVENESS OF FABRICATED, IRRADIATED MEAT ROLLS. J. S. Cohen and L. J. Rice. TR-74-45-FL, April 1974 (AD 786 523).
- R-22-T DEVELOPMENT OF IRRADIATED BEEF.  
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II. Effects of Irradiation Temperature and Dose on the Quality of Roast Beef. G. W. Shults and E. Wierbicki (US Army Natick Laboratories). TR-74-56-FL, July 1974 (AD 786 539).
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G. W. Shults and E. Wierbicki. TR-75-8-FEL, July 1974 (AD 787 279).
- R-25-T CHANGES IN THE SENSORY CHARACTERISTICS, TEXTURE, AND ORGANIC VOLATILES OF IRRADIATED AND NON-IRRADIATED PORK CHOPS.  
G. W. Shults, J. J. Howker, and E. Wierbicki. TR-75-114-FEL. April 1975.
- R-26-T THE EFFECT OF IRRADIATION DOSE AND TEMPERATURE ON CURED HAM.  
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- R-28-T EFFECTS OF NaCl, PHOSPHATES AND OTHER CURING INGREDIENTS ON THE WATER-HOLDING CAPACITY OF LEAN PORK MEAT AND THE QUALITY OF HAM.  
E. Wierbicki, J. J. Howker, and G. W. Shults. TR-76-24-FEL, August 1975.
- R-29-C RADIATION-INACTIVATION OF MEAT PROTEASES AS DETERMINED BY A  $^{14}\text{C}$  LABELLED HEMOGLOBIN METHOD.  
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- R-31-S RESULTS OF ASSAY OF RADIATION STERILIZED BEEF FOR INDUCED ACTIVITY.  
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- R-32-T EFFECT OF COMBINED IRRADIATION AND THERMAL PROCESSING ON CANNED BEEF.  
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- R-33-T RADURIZATION OF FRESH POULTRY.  
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- R-34-T THE EFFECTS OF RADURIZATION ON THE pH, FREE WATER, MEAT SWELLING AND VOLATILE ORGANIC COMPOUND CONCENTRATIONS OF STORED CHICKEN MEAT.  
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- P-2-T PROCESS FOR INACTIVATING ENZYMES IN MEAT TO BE STABILIZED BY IRRADIATION.  
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- P-4-T PROCESS FOR PREPARING STERILIZED COMMINUTED BEEF PRODUCTS.  
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- P-5-T PROCESS FOR STABILIZING STRUCTURE OF GROUND MEAT.  
G. W. Shults and E. Wierbicki, US Army Natick Laboratories; US Patent No. 3,642,500 (10 February 1972).
- P-6-P METHOD FOR PACKAGING FLEXIBLE PACKAGES IN CYLINDRICAL CONTAINERS.  
F. Heiligman, US Army Natick Laboratories; US Patent No. 3,645,759 (29 February 1972).
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G. W. Shults and E. Wierbicki, Patent No. 3,845,227 (29 October 1974).

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- T-1-T RADIATION STERILIZATION OF FOOD IN THE U.S.A.  
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- T-4-T NUCLEAR APPLICATIONS IN THE FOOD INDUSTRY.  
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- T-6-T HIGH DOSE RADIATION PROCESSING OF MEAT, POULTRY AND SEAFOOD PRODUCTS.  
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- T-7-E FACTORS INFLUENCING ECONOMIC EVALUATION OF IRRADIATION PROCESSING.  
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### S-1-M COMPARATIVE RESISTANCE OF STRAINS OF CLOSTRIDIUM BOTULINUM TO GAMMA RAYS.

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- M-1-W Technology of Next Meats for the Wholesomeness Studies - Chicken and Pork.  
G. W. Shults, ABMPS No. 48 Interim Report, April 1974, Natick, MA.

Paper outlines the technological requirements, technical and commercial applications, and quality parameter of two items to be used for wholesomeness testing of radappertized meats. Presented to the NAS - NRC Committee on Food Irradiation.

- M-2-T Low Nitrate/Nitrite Ham.  
E. Wierbicki, ABMPS No. 48 Interim Report, April 1974, Natick, MA.

The paper outlines research in the reduction of curing additives in cured meats. The objective was to lower the total additive content for radappertized ham. Presented to the NAS - NRC Committee on Food Irradiation.

- M-3-T Storage Studies of Irradiated Foods.  
F. Heiligman, ABMPS No. 48 Interim Report, April 1974.

The paper described storage stability of six radappertized items. Storage results up to 4 years were reported. Presented to the NAS - NRC Committee on Food Irradiation.

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- M-6-T Key Technology Parameters of Radappertized Foods.  
E. Wierbicki, ABMPS Report No. 38, Committee on Food Radiation Research, NAS/NRC, Washington, DC, August 1973 (pages 19-22).

- M-7-W Key Technology Parameters of Radappertized Meats (Beef, Chicken, Pork, Ham).  
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- M-8-W Beef for the Wholesomeness Studies - Industrial Procurements.  
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- M-14-C Radiolysis of Iron-Containing Food Component System.  
P. A. Hurwitz, In Minutes, 1974 Annual Meeting, Interdepartmental Committee on Radiation Preservation of Food, Natick, MA, April 1975.

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- M - Technical Papers for Management
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 Kooij, J. V. S-116-T, S-133-W  
 Krushchev, V. G. B-14-T  
 Land, E. S. S-47-C  
 Landers, M. F. S-31-T  
 Larkin, E. P. S-55-M, S-72-M  
 Learson, R. J. S-37-T  
 Levinson, H. S. S-98-M  
 Long, F. E. R-5-P  
 Losty, T. S-51-C, S-66-C  
 MacDonald, B. A. S-121-O  
 Maes, E. S-123-C  
 Martin, T. G., III R-4-S, R-16-S, R-31-S, S-53-S, S-132-S  
 Mason, V. C. S-101-T, S-104-T, S-105-T, S-116-W, S-117-T, S-118-T  
 Maxcy, R. B. R-20-M  
 McAdoo, D. J. S-17-C, S-21-C  
 McLaughlin, W. L. R-18-D, T-12-D  
 Mehrlich, F. P. S-7-T  
 Merritt, C., Jr. B-21-C, T-10-T, S-17-C, S-21-C, S-63-C, S-94-C,  
 S-102-W, S-135-C  
 Metlitskii, L. V. B-14-T  
 Meyer, R. A. R-2-C  
 Neta, P. S-39-C, S-40-C, S-57-C, S-112-C  
 Nielsen, W. S-65-N

Osburn, J. W., Jr. B-7-E, B-20-E

Payne, G. O., Jr. R-1-P, R-5-P, S-6-T

Pederson, A. J. R-3-T

Peeler, J. T. S-55-M, S-72-M

Phillips, C. E. S-5-T, S-24-T

Powers, E. M. S-59-T

Pratt, G. B. R-15-C, S-20-C, S-78-P, S-82-P

Previte, J. J. S-27-M, S-28-T

Raheja, K. S-14-T

Raica, N., Jr. S-35-W, S-65-N

Rao, B. Y. K. R-19-T

Rao, P. S. S-87-C

Read, R. B., Jr. S-55-M

Reber, E. F. S-14-T

Rees, C. W. S-122-O

Rentmeester, K. R. S-78-P

Rhee, C. S-129-M

Rice, L. J. R-21-T, S-50-T, S-58-T

Robbins, F. M. T-13-C, M-13-C

Rogachev, V. N. B-14-T

Ronsivalli, L. J. R-14-T, S-37-T

Ross, E. M., Jr. S-83-M, S-84-M, S-97-M

Roth, J. S. S-51-C, S-66-C

Rowley, D. B. R-8-M, R-30-M, T-2-M, T-10-T, S-32-M, S-43-M,  
S-61-M, S-80-T, S-96-T, S-97-M, S-98-M, S-130-M

Russell, D. P. S-60-T

Scarpino, D. P. S-72-M

Schneider, M. D. S-8-T

Scott, J. S-65-N

Shattuck, E. S-97-M

Shauwaert, F. S-123-C

Shults, G. W. P-1-T, P-2-T, P-3-T, P-4-T, P-5-T, P-7-T, R-19-T,  
R-20-T, R-22-T, R-23-T, R-24-T, R-25-T, R-26-T,  
R-27-T, R-28-T, R-29-C, R-32-T, R-35-T, S-7-T,  
S-13-T, S-60-T, S-66-C, S-74-T, S-94-C, S-99-T,  
S-100-T, S-101-T, S-103-T, S-104-T, S-105-T,  
S-117-T, S-118-T, M-1-W

Simic, M. G. S-38-C, S-39-C, S-40-C, S-44-C, S-45-C, S-47-C,  
S-48-C, S-56-C, S-57-C, S-73-C, S-85-C, S-86-C,  
S-87-C, S-88-C, S-92-C, S-93-C, S-108-C, S-110-C,  
S-112-C, S-126-C

Simon, M. S-4-T, S-8-T, S-31-T

Sinnhuber, R. O. R-10-T, S-31-T

Snyder, O. P. T-2-M, S-7-T, S-12-M

Spiegl, C. H. R-1-P, R-5-P

Spracklin, B. W. S-37-T

Strojan, C. S-62-T

Sullivan, R. S-55-M, S-72-M

Swallow, A. J. S-47-C

Swantak, W. S-62-T

Taub, I. A. T-13-C, S-93-C, S-102-W, S-111-C, S-124-C, S-125-C,  
S-126-C, M-9-C, M-10-C

Thomas, M. H. R-9-N, T-6-T, T-10-T, S-42-N, S-77-N, S-136-N

Thompson, M. H. R-7-T

Tobback, F. S-123-C

Tocci, J. S-93-C

Tompkin, R. B. S-16-M

Wadsworth, C. K. S-13-T, S-24-T, S-41-T

Walker, A. A. S-12-M, S-52-M

Walker, J. E. T-13-C, S-125-C, M-12-C

Wall, M. A. S-49-T

Wasserman, A. E. S-82-T, S-114-T

Waters, M. E. R-7-T

Werkowski, S. S-29-M, S-54-M

Whaley, D. N. S-97-M

Wiatre, C. L. S-129-M

Wierbicki, E. R-9-N, R-17-T, R-19-T, R-20-T, R-22-T, R-23-T, R-24-T,  
R-25-T, R-26-T, R-27-T, R-28-T, R-29-T, R-32-T,  
R-33-T, R-34-T, P-2-T, P-5-T, P-7-T, T-5-T,  
T-6-T, T-10-T, S-4-T, S-15-T, S-18-P, S-30-E, S-34-T,  
S-41-T, S-51-C, S-60-T, S-68-T, S-74-T, S-75-T,  
S-88-P, S-79-T, S-80-T, S-82-T, S-89-T, S-94-C,  
S-96-T, S-99-T, S-100-T, S-103-T, S-107-T, S-114-T,  
S-116-W, S-117-T, S-118-T, S-127-P, S-128-P, M-2-T,  
M-4-T, M-5-T, M-6-T, M-7-T, M-8-T

Yu, T. C. S-31-T